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Noninvasive Detection of Total Occlusion of the Left Anterior Descending Coronary Artery With Transthoracic Doppler Echocardiography

Nozomi Watanabe, MD, Takashi Akasaka, MD, Yasuko Yamaura, MD, Maki Akiyama, MD, Yuji Koyama, MD, Norio Kamiyama, MD, Yoji Neishi, MD, Shuichiro Kaji, MD, Yasuhiro Saito, MD, Kiyoshi Yoshida, MD, FACC

Kurashiki, Japan

OBJECTIVES The purpose of this study was to evaluate the value of transthoracic Doppler echocardiography (TTDE) for the noninvasive detection of total left anterior descending coronary artery (LAD) occlusion.

BACKGROUND Total coronary occlusion is associated with an adverse long-term prognosis, and mechanical revascularization may be required for the patient with total coronary occlusion. However, a noninvasive diagnosis of total coronary occlusion before coronary angiography (CAG) has been difficult, especially in patients without clinical signs.

METHODS We studied 103 consecutive patients who underwent CAG for the evaluation of coronary artery disease. The study group consisted of 16 patients with total LAD occlusion (group A) and 87 patients without total LAD occlusion (group B). Coronary flow velocity in the mid-portion of the LAD was recorded by TTDE.

RESULTS Adequate spectral Doppler recordings of diastolic flow in the LAD were obtained in 98 study patients (95%; 15 patients in group A and 83 patients in group B). In group A, retrograde LAD flow was obtained in 14 (93%) of 15 patients. The mean diastolic velocity of the retrograde flow was 21.0 ± 6.1 cm/s. In group B, antegrade LAD flow was obtained in all 83 patients (100%). The mean diastolic velocity of the antegrade flow was 21.5 ± 7.1 cm/s. Retrograde LAD flow by TTDE had a sensitivity of 93% and a specificity of 100% for the detection of total LAD occlusion.

CONCLUSIONS Retrograde flow in the LAD by TTDE is a highly sensitive and specific finding that can be used to noninvasively diagnose total LAD occlusion. (J Am Coll Cardiol 2001;38:1328–32)
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It has been reported that an occluded coronary artery treated medically is associated with a high incidence of cardiac events (1–3). Some previous studies have suggested that patients with total coronary occlusions may benefit from mechanical revascularization, regardless of the severity of the angina pectoris (4–8). Today, a definite diagnosis of total coronary occlusion can be made by coronary angiography (CAG). Once ischemia or other clinical signs are detected, CAG would be performed to delineate the coronary anatomy. However, CAG is an invasive technique and only available in the catheterization laboratory. Patients without anginal symptoms, left ventricular dysfunction or electrocardiographic (ECG) changes may not be diagnosed until cardiac events occur. If noninvasive detection of total coronary occlusion before CAG becomes possible, it could help in the consideration of further invasive procedures and in the estimation of the results of various interventions. Recently, noninvasive measurements of coronary flow velocity in the left anterior descending coronary artery (LAD) have become possible by using transthoracic Doppler echocardiography (TTDE), which is widely used in the clinical setting (9–16). The purpose of this study was to evaluate the value of TTDE for the noninvasive detection of total LAD occlusion.

From the Department of Cardiology, Kawasaki Medical School, Kurashiki, Japan.
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METHODS

Study patients. We prospectively examined 103 consecutive patients (76 men and 27 women; mean age 64.7 ± 9.3 years) who underwent CAG for the evaluation of coronary artery disease. Patients with an acute myocardial infarction (AMI) or previous coronary artery bypass graft surgery (CABG) were not included in this study. The underlying diseases seen before CAG were an old myocardial infarction in 20 patients, effort angina in 54 patients, unstable angina in 23 patients and vasospastic angina in 6 patients. Sixteen of the 103 patients had total occlusion of the proximal or mid-portion of the LAD (group A). The remainder did not have total occlusion of the proximal or mid-portion of the LAD (group B). In group B, the average stenosis was 41 ± 35% by quantitative CAG, including 20 patients with a normal LAD. All participants gave written, informed consent to the study protocol, which was approved by the

Abbreviations and Acronyms

AMI = acute myocardial infarction
CABG = coronary artery bypass graft surgery
CAG = coronary angiography
ECG = electrocardiographic
LAD = left anterior descending coronary artery
TTDE = transthoracic Doppler echocardiography

Committee for the Protection of Human Subjects in Research at Kawasaki Medical School.

Recording of LAD flow by TTDE. The TTDE examinations were performed with a digital ultrasound system (HDI 5000, ATL Inc., Bothell, Washington) with a Doppler frequency of 4.0 MHz. All examinations were performed before CAG by one investigator who had no knowledge of the other patient data. For color Doppler flow mapping, the velocity range was set at ±9.6 to 28.8 cm/s. The color gain was adjusted to provide the optimal images. The acoustic window was around the mid-clavicular line in the fourth or fifth intercostal space, with the patient placed in the left lateral decubitus position. The ultrasound beam was transmitted toward the heart to visualize coronary blood flow in the mid-portion of the LAD by using color Doppler flow mapping. In the short-axis images of the left ventricle, the mid-portion of the LAD can be identified as a cross section of the tubular structure containing the color Doppler flow signal, positioned in the anterior interventricular sulcus. After confirming its position, the transducer was rotated counterclockwise to visualize the LAD, which runs along the interventricular sulcus, in the long-axis section (Fig. 1). After positioning a sample volume (1.5 to 2.5 mm wide) on the color signal in the LAD, Doppler spectral tracings of flow velocity were recorded by the pulsed Doppler method. Angle correction was needed in each examination (incident angle 41 ± 11°). All studies were recorded on s-VHS videotape. Using the computer analysis system incorporated in the ultrasound system, off-line measurements of mean diastolic velocities and peak diastolic velocities were performed by tracing the contour of the spectral Doppler signal.

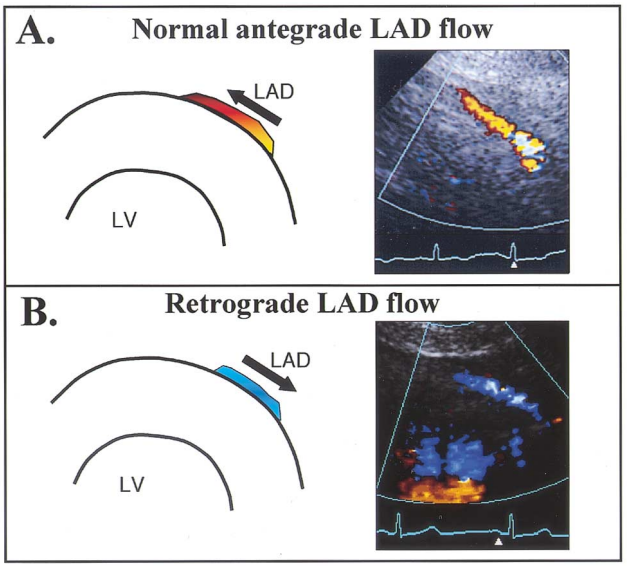

Figure 1. The left anterior descending coronary artery (LAD) flow signal by transthoracic Doppler echocardiography (TTDE). Schematic representation **(left)** and TTDE image **(right)** showing normal antegrade LAD flow signal toward the apex **(A)** and retrograde LAD flow signal toward the base of the heart **(B)**. LV = left ventricle.

Analysis of LAD flow velocity data. Data are expressed as the mean value ± SD. We examined the sensitivity and specificity of retrograde LAD flow for the diagnosis of total LAD occlusion. Interobserver and intraobserver variabilities were assessed for mean and peak diastolic velocities in 10 randomly selected recordings. Interobserver variability was calculated as the standard deviation of the differences between the measurements of two independent observers who were unaware of the other data, and expressed as a percentage of the average value. Intraobserver variability was calculated as the standard deviation of the differences between the first and second determinations (three-week interval) for a single observer, and expressed as a percentage of the average value.

RESULTS

Adequate spectral Doppler recordings of diastolic coronary flow in the LAD were obtained in 98 (95%) of 103 study patients (15 of 16 patients in group A; 83 of 87 patients in group B). Success rates in male and female patients were 94.7% and 96.3%, respectively. There were no significant differences in age (64 ± 9 years vs. 65 ± 8 years, p = NS) or body mass index (25 ± 8 kg/m^2 vs. 26 ± 7 kg/m^2, p = NS) between the successful and unsuccessful groups. In group A, diastolic retrograde LAD flow toward the base of the heart was obtained in 14 (93%) of 15 patients (Fig. 2). Mean and peak diastolic velocities in retrograde flow were 21.0 ± 6.1 cm/s and 28.1 ± 7.4 cm/s, respectively. In 1 (7%) of 15 patients in group A, antegrade LAD flow was obtained. This patient had an uncommon collateral channel to the LAD through the conus branch, wherein the sample volume was located distal to the collateral input origin. In group B, diastolic antegrade LAD flow toward the apex was obtained in all 83 patients (Fig. 3). Mean and peak diastolic velocities in antegrade flow were 21.5 ± 7.1 cm/s and 31.4 ± 11.7 cm/s, respectively. There was no significant difference in mean diastolic flow velocity in the LAD between patients who had LAD stenosis that was not an occlusion and patients who had a normal LAD (21 ± 7 cm/s vs. 23 ± 8 cm/s, p = NS). There was no significant difference in mean diastolic velocity in the LAD between patients who had coronary disease in other vessels and those who had normal coronary arteries (21 ± 3 cm/s vs. 22 ± 7 cm/s, p = NS). Retrograde LAD flow by TTDE had a sensitivity of 93% and a specificity of 100% for the detection of total LAD occlusion.

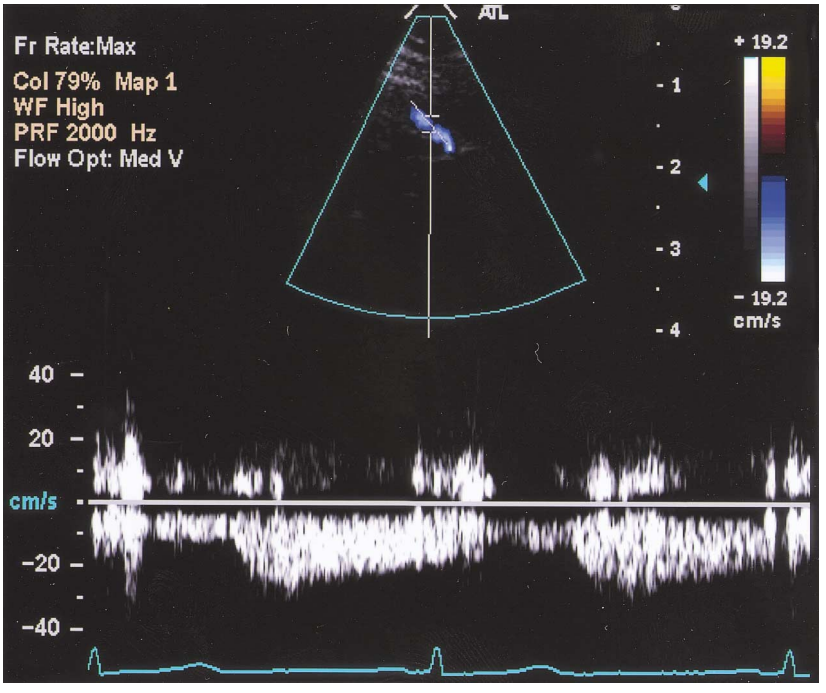

Figure 2. Retrograde left anterior descending coronary artery flow velocity by pulsed Doppler echocardiography.

Observer variability. Interobserver and intraobserver variabilities for mean diastolic velocity were 4.3% and 3.3% and for peak diastolic velocity, 3.7% and 3.1%, respectively.

DISCUSSION

In the present study, we evaluated the value of coronary flow measurements using TTDE for the detection of total LAD occlusion. The present study demonstrated that retrograde flow in the LAD by TTDE was a highly sensitive and specific finding in the noninvasive diagnosis of total LAD occlusion.

Retrograde LAD flow recording by TTDE. After occlusion of a major epicardial coronary artery, blood flow to the previously supplied myocardium must arrive through coronary collateral vessels. Retrograde blood flow velocity distal to a totally occluded coronary vessel represents collateral flow to the occluded region. Recently, Kern et al. (17–20) reported that flow beyond chronically occluded artery seg-

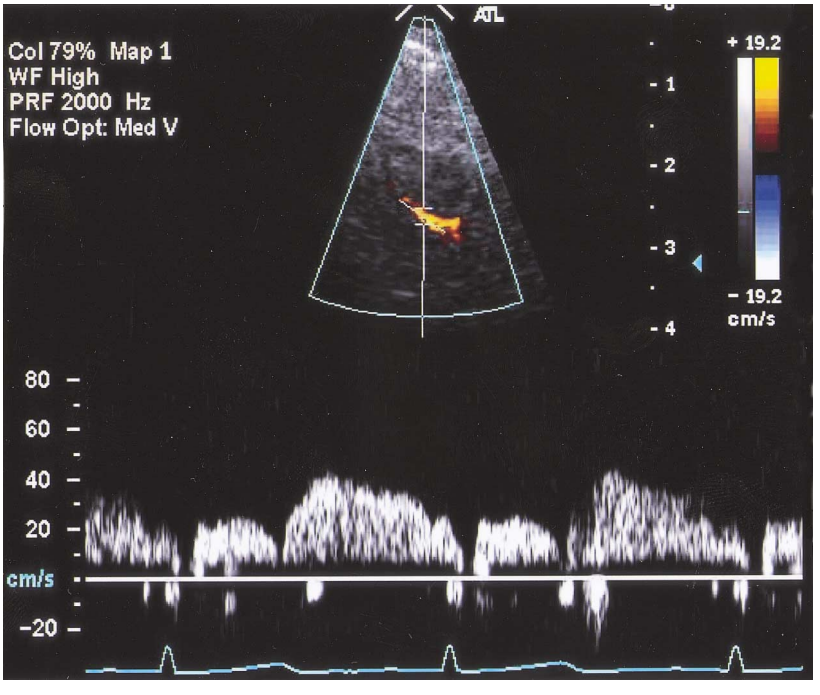

Figure 3. Normal antegrade left anterior descending coronary artery flow velocity by pulsed Doppler echocardiography.

ments supplied by collateral vessels could be studied quantitatively after crossing the obstruction with the invasive use of the Doppler guide wire. Transthoracic Doppler echocardiography allows noninvasive and quantitative measurement of coronary blood flow velocity beyond totally occluded arterial segments.

Previous studies have reported that coronary flow velocity can be measured successfully with the guidance of color flow mapping (14–16). With regard to the learning curve for the detection of the LAD flow signal, we have previously examined the success rate in our laboratory. The success rate for detecting the LAD flow signal was 48 ± 12% for the first 30 studies, 79 ± 13%, for the next 30 studies (total 60 studies) and 82 ± 14% for the next 30 studies (total 90 studies). The success rate reached 92 ± 7% in the last 30 studies (total 120 studies). In the present study, LAD flow velocity could also be assessed with a high success rate (95%). The present study establishes several potentially useful features of the noninvasive assessment of retrograde LAD flow by TTDE. This modality can be performed in an outpatient setting, and serial assessments can be performed.

Noninvasive diagnosis of total LAD occlusion. Previous studies have suggested that an occluded coronary artery treated medically is associated with a high risk of cardiac events. Puma et al. (1) investigated the prognosis of patients with one-vessel disease with total occlusions and found that the five-year event (e.g., death, AMI, CABG) rate was 34%. In patients with single-vessel disease followed up for a mean of 48 months, total coronary occlusion was associated with a significantly higher incidence of sudden death than was high grade stenosis (15% vs. 3%) (2). Wiggers et al. (4) reported that the five-year event rates (e.g., death, AMI, CABG) of medically treated patients with mild or absent anginal symptoms were significantly higher than those of surgically treated patients with severe anginal symptoms (34% vs. 16%). Similarly, several investigators have reported better survival in patients with successful coronary angioplasty of a chronic total occlusion than in those whose procedure failed (5,21). These data indicate that revascularization should be considered in patients with chronic total coronary occlusions. Today, noninvasive diagnosis of total coronary occlusion before CAG has been difficult, especially in patients without anginal symptoms, left ventricular dysfunction or ECG changes. Danchin et al. (6) studied patients who developed a new total coronary occlusion during the period between diagnostic CAG and repeat CAG, and they found that most of the patients showed no clinical sign to diagnose the occurrence of spontaneous coronary occlusion. Transthoracic Doppler echocardiography is a completely noninvasive technique that would be helpful in diagnosing total coronary occlusion before CAG.

Study limitations. The present study has some important limitations. First, we examined patients who underwent CAG for the evaluation of coronary artery disease. Patients without any clinical signs were not included in the study group. Second, an occluded LAD, which is filled through uncommon collateral channels as high-lateral branch or conus branch, may have normal antegrade flow in the mid-portion of the LAD. To diagnose these patients, a recording should be made proximal to the junction point of the collateral circulation to the LAD. Finally, in the present study, coronary flow velocity was assessed only in the LAD. Whether this Doppler method can be applied for detecting retrograde flow in other coronary arteries remains to be explored.

Conclusion. Retrograde flow in the LAD, as detected by TTDE, provides highly sensitive and specific findings in the noninvasive detection of total LAD occlusion.

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Reprint requests and correspondence: Dr. Nozomi Watanabe, Department of Cardiology, Kawasaki Medical School, 577 Matsushima, Kurashiki, 701-0192, Japan. E-mail address; non@med.kawasaki-m.ac.jp.

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